FINAL PRESENTATION

Enabling Lead-Free Interconnects in DoD Weapon Systems

ESTCP Project WP-201573-T2

SEPTEMBER 2017

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Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

An ***enhanced multi-pronged technology transfer approach*** will be designed to communicate the results of the SERDP lead-free projects to various stake-holders and to enable standardization. The work products and transferred data *must not* be technical information, whose export is governed by the International Traffic in Arms Regulations (ITAR). The DoD may choose to have separate ITAR information transfer if they deem it necessary to convey key issues to select audiences. The following novel transfer methods are planned:

(1) Develop tailored Lead-free webinars for the Program Management and Systems Engineering. These webinars target interconnect reliability and whisker risk to the needs of the weapon system program managers. Examples of risk will be given and information will be provided on where to access more detailed technical support.

(2) Transfer of the whisker risk modeling developed under WP1753, including tutorials on the WhiskerRisk Tool and the spreadsheet calculator, to the University of Maryland Center for Advanced Life Cycle Engineering (CALCE).

(3) Exchange information and results from the SERDP and ESTCP lead-free effort with the IPCPERM working groups.

15. SUBJECT TERMS

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a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Stephan Meschter
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DoD Lead-free Electronics Risk Mitigation: WP-201573T2 Summary

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Dr. Peter Borgesen, Binghamton University
Dr. Indranath Dutta, Washington State University

Strategic Environmental Research and Development Program (SERDP)
Environmental Security Technology Certification Program (ESTCP)

WP-201573T2 Team and tasks

- Project lead S. Meschter, BAE Systems
- Team
  - Dr. Stephan Meschter, BAE Systems
  - Dr. Peter Borgesen, Binghamton University
  - Dr. Indranath Dutta, Washington State University
  - Dr. Michael Osterman, CALCE University of Maryland
- Tasks
  - Transfer SERDP WP1751 Research (Borgesen & Dutta)
    - IPC-PERM and GEIA-STD-0005-X Standards
  - Transfer WP1753 tin whisker risk calculator
    - CALCE site (Meschter, McKeown, Osterman, UMD Student)
  - Webinars for Program Managers and Systems engineers (Principle presenter)
    - Lead-free overview (Meschter)
    - Solder basics (Borgesen and Dutta)
    - Tin whisker basics (Osterman)

SERDP/ESTCP lead-free projects

- **Prior DoD Lead-free Electronics Risk Mitigation Webinars**
  - **Understanding and Mitigating the Risks Associated with Lead-Free Electronics March 2015**
    - https://serdp-estcp.org/content/download/32643/318678/file/Lead%20Free%20Webinar%20Slides.pdf
  - **Program Management and Systems Engineering Overview Oct. 2016**
    - http://www.calce.umd.edu/seminars/PM-LF-Webinar-2016-10-12.htm
  - **Lead-free Solder Basics for Systems Engineers March 2017**
    - http://www.calce.umd.edu/seminars/SR-LF-Webinar-2017-03-14.htm
  - **Tin Whisker Basics for Systems Engineers Sept 2017**
    - http://www.calce.umd.edu/lead-free/ and http://www.calce.umd.edu/seminars/serdpestcpwebinar-whiskers.htm
- **Whisker Risk Calculation Spreadsheet hosted at CALCE**
  - http://www.calce.umd.edu/tin-whiskers/spreadsheet/
- **Active projects**
  - **Novel Whisker Mitigating Composite Conformal Coat Assessment**
    - **SERDP WP-2213 Dr. Stephan Meschter, BAE Systems, May 2012-Present**
    - https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Lead-Free-Electronics/WP-2213
  - **Enabling Lead-free Interconnects in Weapon Systems**
    - **ESTCP WP-201573-T2 Dr. S. Meschter**
- **Complete projects**
  - **The Role of Trace Elements in Tin Whisker Growth**
    - **SERDP WP-1751 Dr. Jean Nielsen, The Boeing Company, Sept. 2013**
    - https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Lead-Free-Electronics/WP-1751
  - **Microstructurally Adaptive Constitutive Relations and Reliability Assessment Protocols for Lead Free Solder**
    - **SERDP WP-1752 Dr. Peter Borgesen, Binghamton University, May 2015**
    - https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Lead-Free-Electronics/WP-1752
  - **Tin Whisker Testing and Modeling**
    - **SERDP WP-1753 Dr. Stephan Meschter, BAE Systems, Dec 2015**
    - https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Lead-Free-Electronics/WP-1753
  - **Contributions of Stress and Oxidation on the Formation of Whiskers in Lead-Free Solders**
    - **SERDP WP-1754 Dr. Elizabeth Hoffman, Savannah River National Laboratory, Jan 2016**
    - https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Lead-Free-Electronics/WP-1754
  - **Tin Whiskers Inorganic Coatings Evaluation (TWICE)**
    - **SERDP WP-2212 Mr. David Hillman, Rockwell Collins, Inc., Jan. 2015**
    - https://www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Lead-Free-Electronics/WP-2212

TRANSFER TO IPC-PERM GROUP DOCUMENTS GEIA-STD-0005-XX

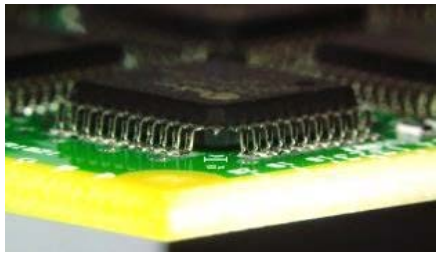
IPC = Association for Interconnecting Printed Circuits
PERM = Pb-Free Electronics Risk Management Group

SERDP Research Transfer to PERM

- IPC-PERM Council Coordination for GEIA-HB-0005-2 (Technical Guidelines) or GEIA-STD-0005-3 (Test Standard)
  - Currently managing manpower limitations
  - Neither the GEIA-HB-0005-2 or GEIA-STD-0005-3 has a team available for document revision
  - GEIA-HB-0005-2 issued in 2006 is most in need of revision
- The Pb-Free Electronics Risk Management (PERM) Council Meeting No. 30
  - 2 - 4 November 2016
  - Harris Technology Center
- P. Borgesen and I. Dutta
  - Output of WP1751: Outline of recommended paragraphs to be considered for updating in GEIA-HB-0005-2 and GEIA-STD-0005-3 and the detailed recommended updates to GEIA-HB-0005-2
  - No-Pb Solder Reliability ESTCP webinar preview
- S. Meschter and M. Osterman
  - SERDP/ESTCP Tin whisker risk calculator during the 8-81H Tin whiskers group working session
- GEIA-STD-0005-2 Appendix information added corrosion induced whisker formation discussion from WP1753

WHISKER RISK SPREAD-SHEET

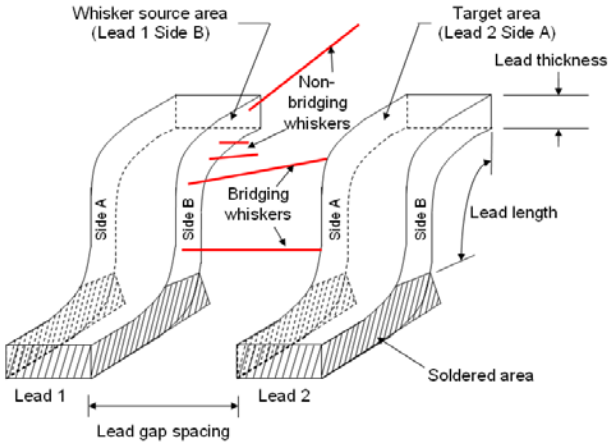
Tin Whisker Risk Assessment Spread-sheet

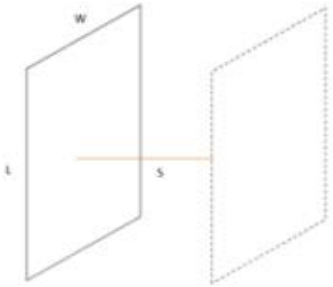


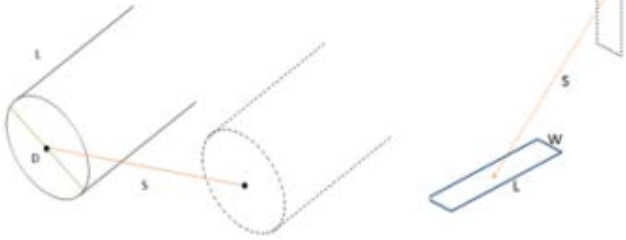
- Part and lead geometry
- Lead, solder, and pad
  - Whisker density
  - Whisker length distribution
- Voltage

123	**WHISKER SHORTING RESULTS:**			
124	**Coating Effectiveness =** 50%			
125	Total lead spaces = 12			
126				
127	**Applied Voltage =** 5 **V**			
128	Shorting Probability = 41.4%			
129	**Whisker Type:**	**Lead**	**Solder**	**Pad**
130	Bridges per lead:	1.773937	1.095674	0.436333
131	Bridges per part:	21.28724	13.14809	5.236
132	Shorts per part:	8.803912	5.437745	2.165489
133	Bridging probability for lead pair:	83.09%	66.62%	35.46%
134	Shorting probability for lead pair:	52.01%	36.45%	16.53%
135	Shorting probability for part:	99.99%	99.57%	88.57%
136	Reliability for not shorting for part:	0.01%	0.43%	11.43%
137				
138	**RELIABILITY (this part only) =** 0.00%			
139	**TOTAL SHORTS (this part only) =** 16.41			

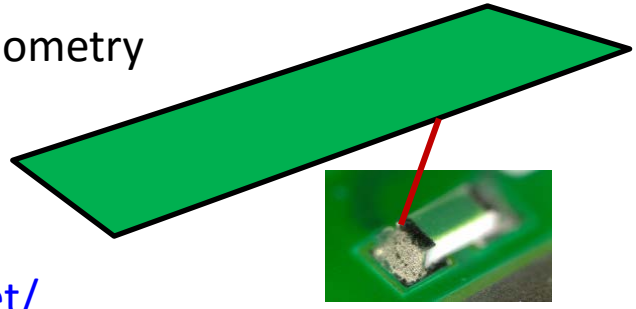
Parts







Primitive Geometry



http://www.calce.umd.edu/tin-whiskers/spreadsheet/

WEBINARS

ESTCP lead-free webinars

- **DoD Lead-free Electronics Risk Mitigation Webinars**
  - **Program Management and Systems Engineering Overview Oct. 2016**
    - http://www.calce.umd.edu/seminars/PM-LF-Webinar-2016-10-12.htm
      - Oct 12, 2016: 33 registered, 15 attended
  - **Lead-free Solder Basics for Systems Engineers March 2017**
    - http://www.calce.umd.edu/seminars/SR-LF-Webinar-2017-03-14.htm
      - March 14, 2017: 45 registered, 12 attended
  - **Tin Whisker Basics for Systems Engineers Sept 2017**
    - http://www.calce.umd.edu/lead-free/

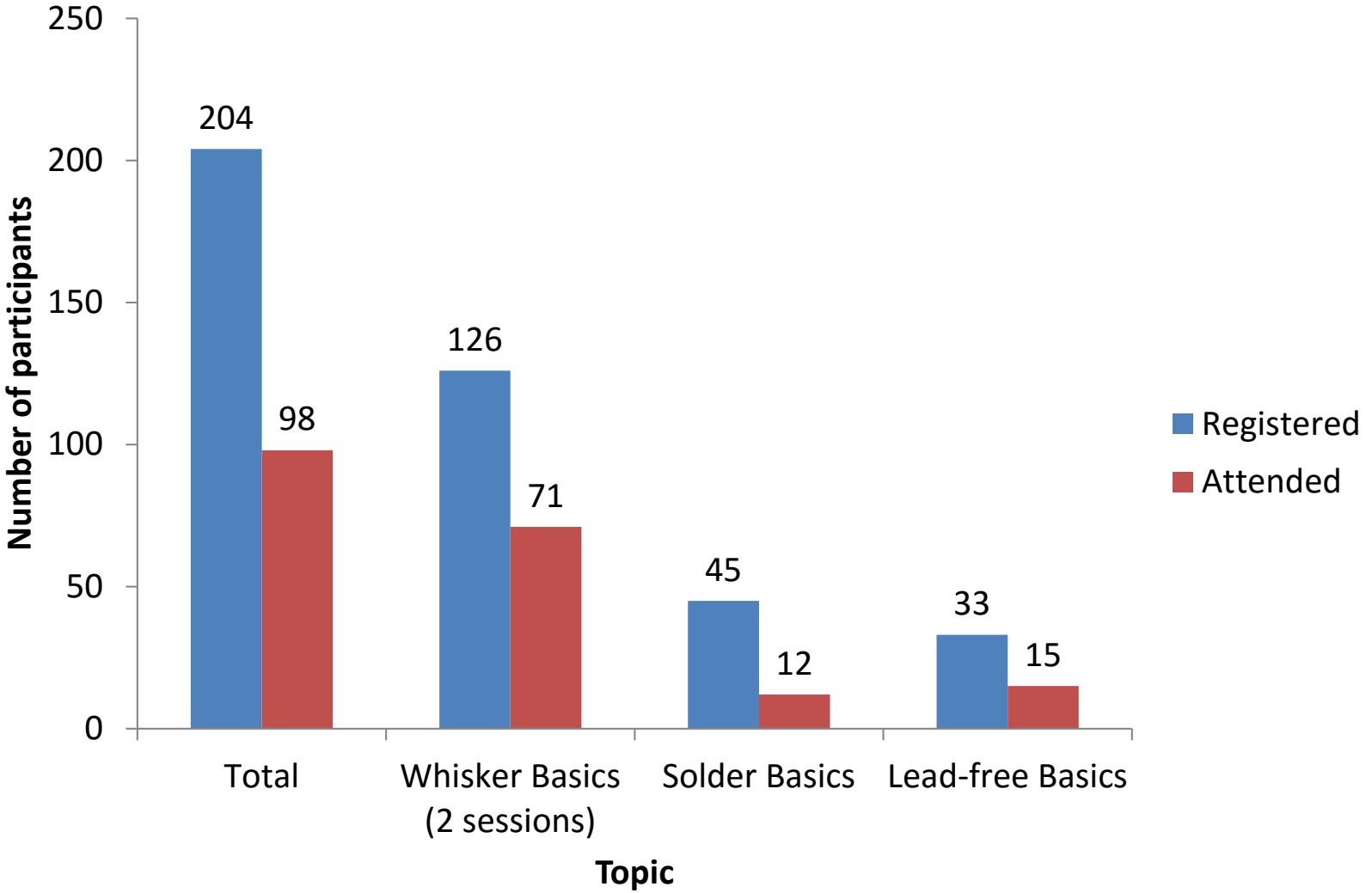
      and
    - http://www.calce.umd.edu/seminars/serdpestcpwebinar-whiskers.htm
    - Two session: 126 registered, 71 attended
      - Sept. 12, 2017: 79 registered, 52 attended
      - Sept. 26, 2017: 47 registered, 18 attended

Topic	Registered	Attended
Lead-free Basics	33	15
Solder Basics	45	12
Whisker Basics (2 sessions)	126	71
Total	**204**	**98**

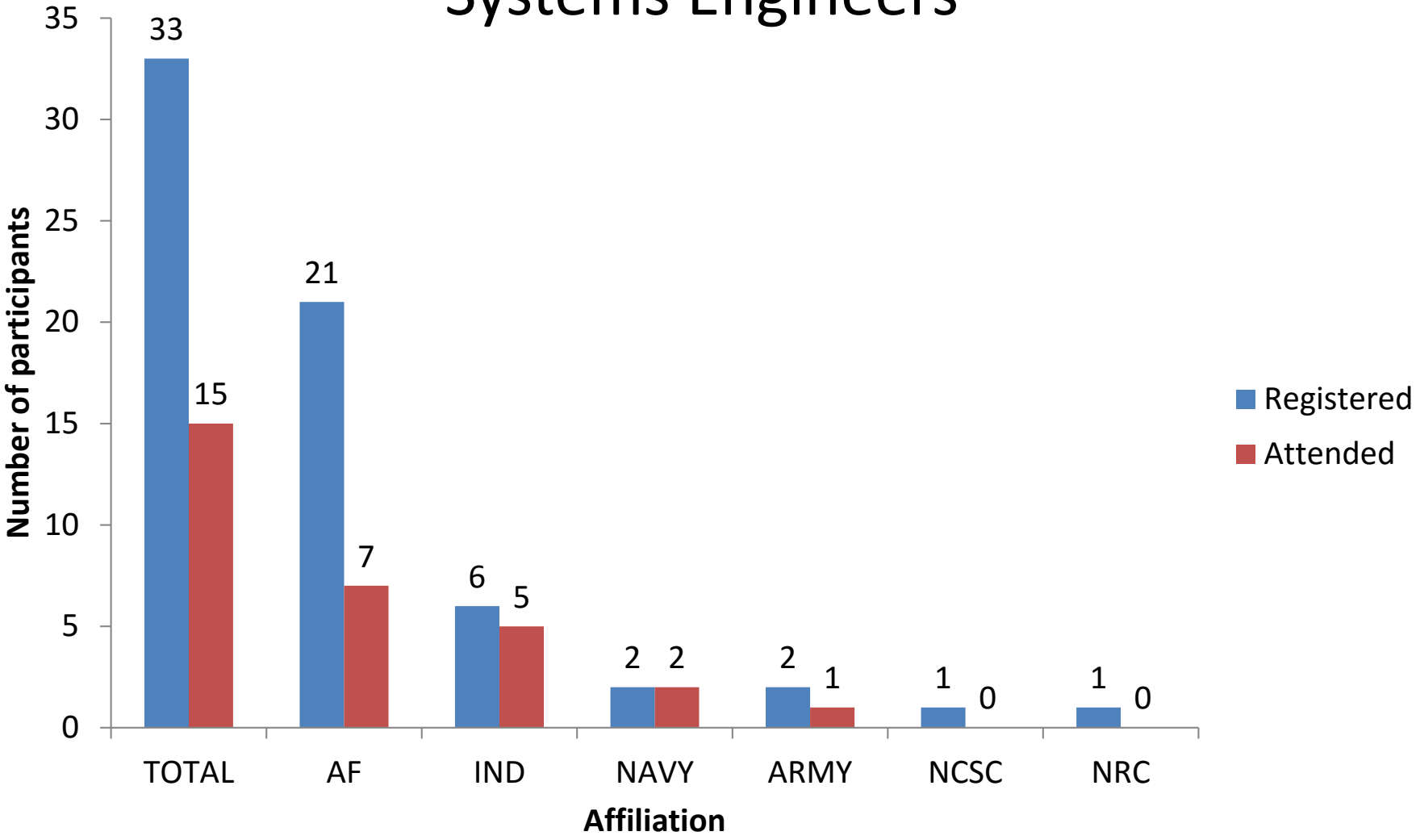
Webinar development and outreach

- Webinar Development Assistance
  - BAE Systems Controls Endicott, NY Senior Systems Engineers/PMs
- Invitations to webinars reached out to:
  - NAVAIR
    - Dave Kayser
  - USARMY RDECOM AMRDEC or MDA
    - Dave Locker, Paul Zutter, Janelle Fowler, Holley Wingard, Jon Ahlbin, Charles Peltier,
  - Air Force
    - Paul Steiner, Tim Kalt, Gary Dowdy
  - NAVSEA
    - Mick Miller, Gary Latta (NAVY Retired)
  - SERDP
    - Braxton Lewis
  - NASA Goddard
    - Henning Leidecker, Lyudmyla Panashchenko, Jay Brusse
  - BAE Army Vehicle PM
  - Industry
    - CALCE Distribution list
    - Bill Rollins Weekly Whisker Group Telecon
    - Bob Rassa NDIA Systems Engineering Division
    - Mark Gordon NDIA Manufacturing Division

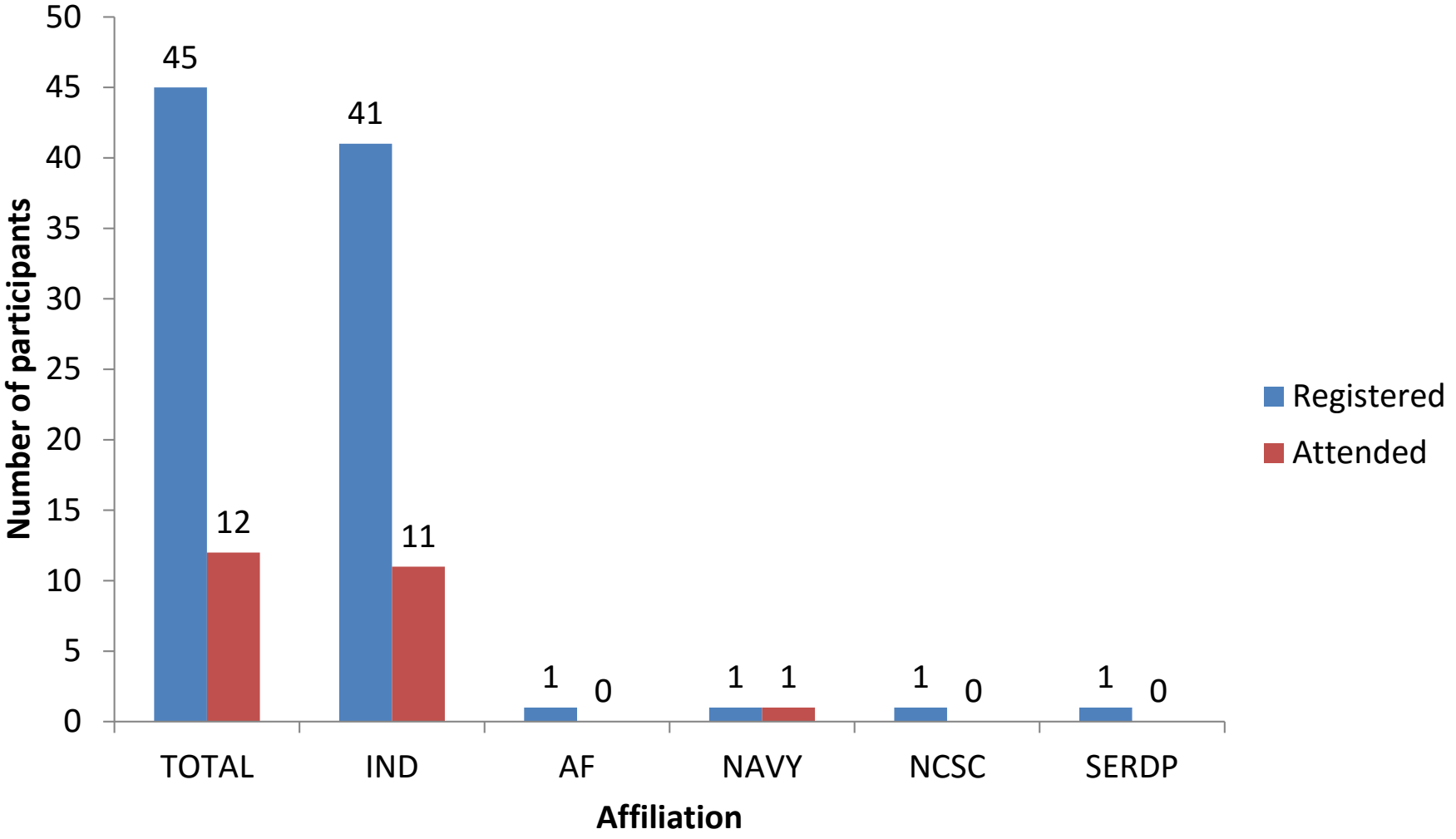
Lead-free risk mitigation basics for Program Managers and Systems Engineers



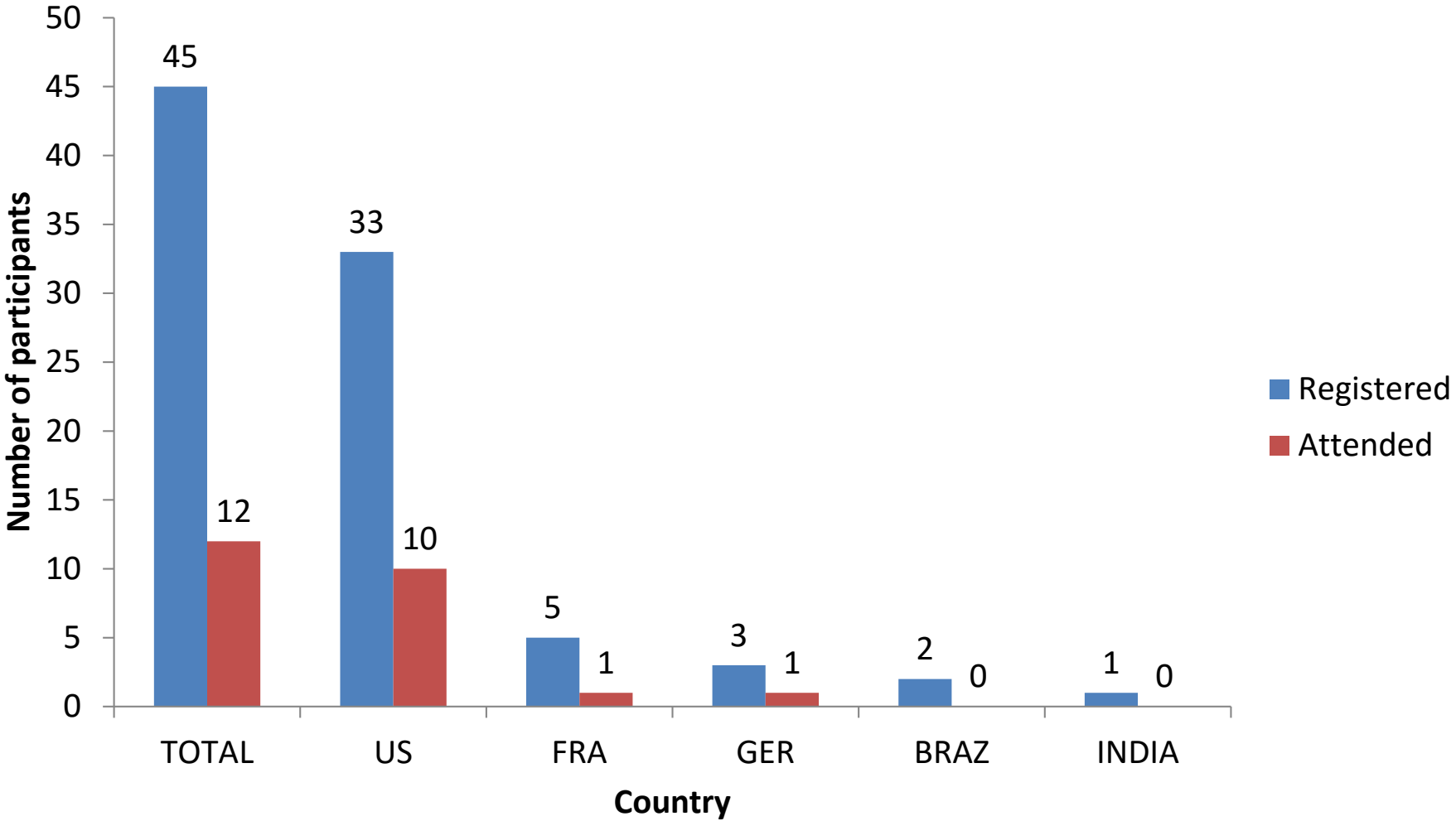
Participation by affiliation: Lead-free Basics for Program Management and Systems Engineers



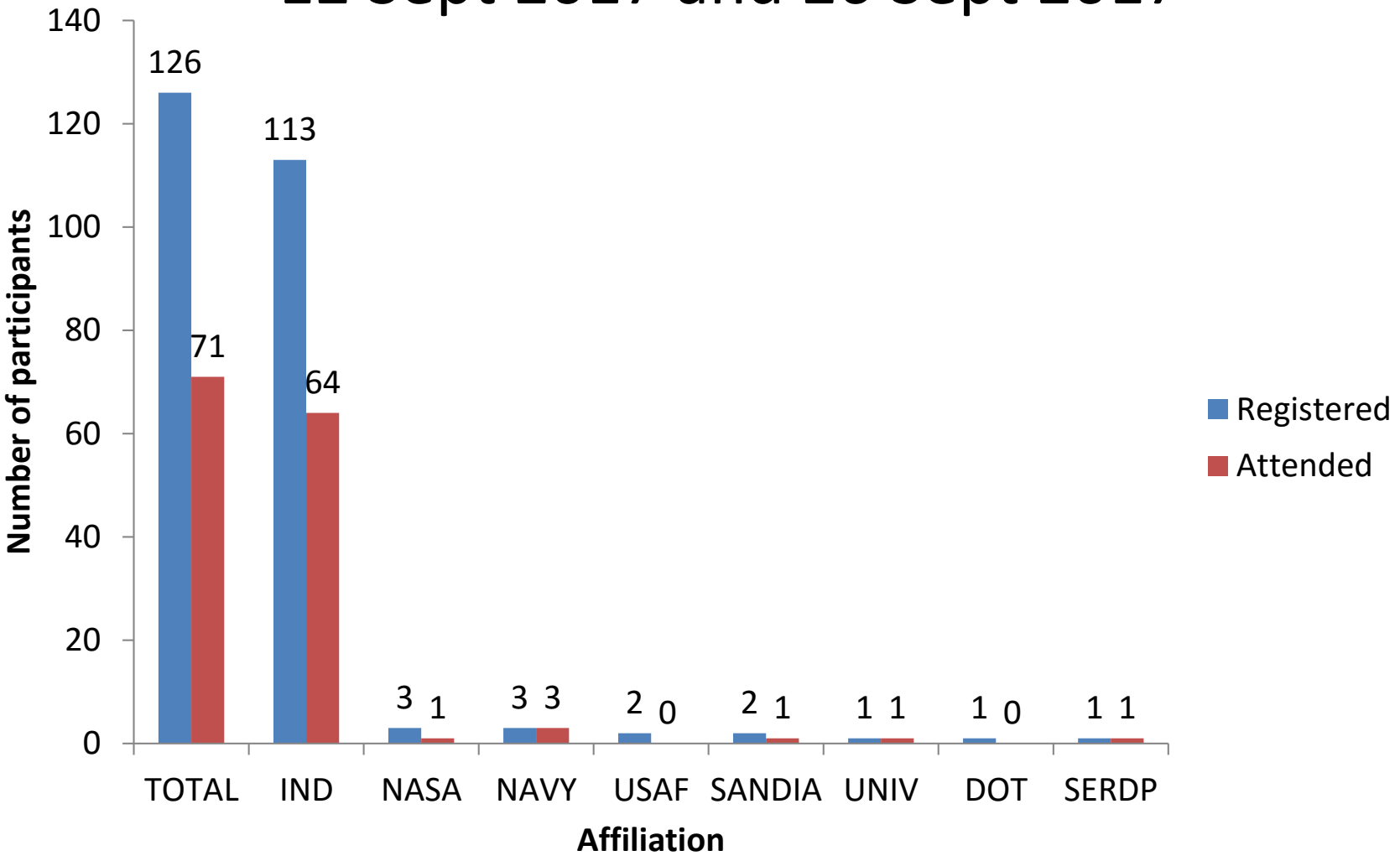
Participation by affiliation: Lead-free Solder Basics



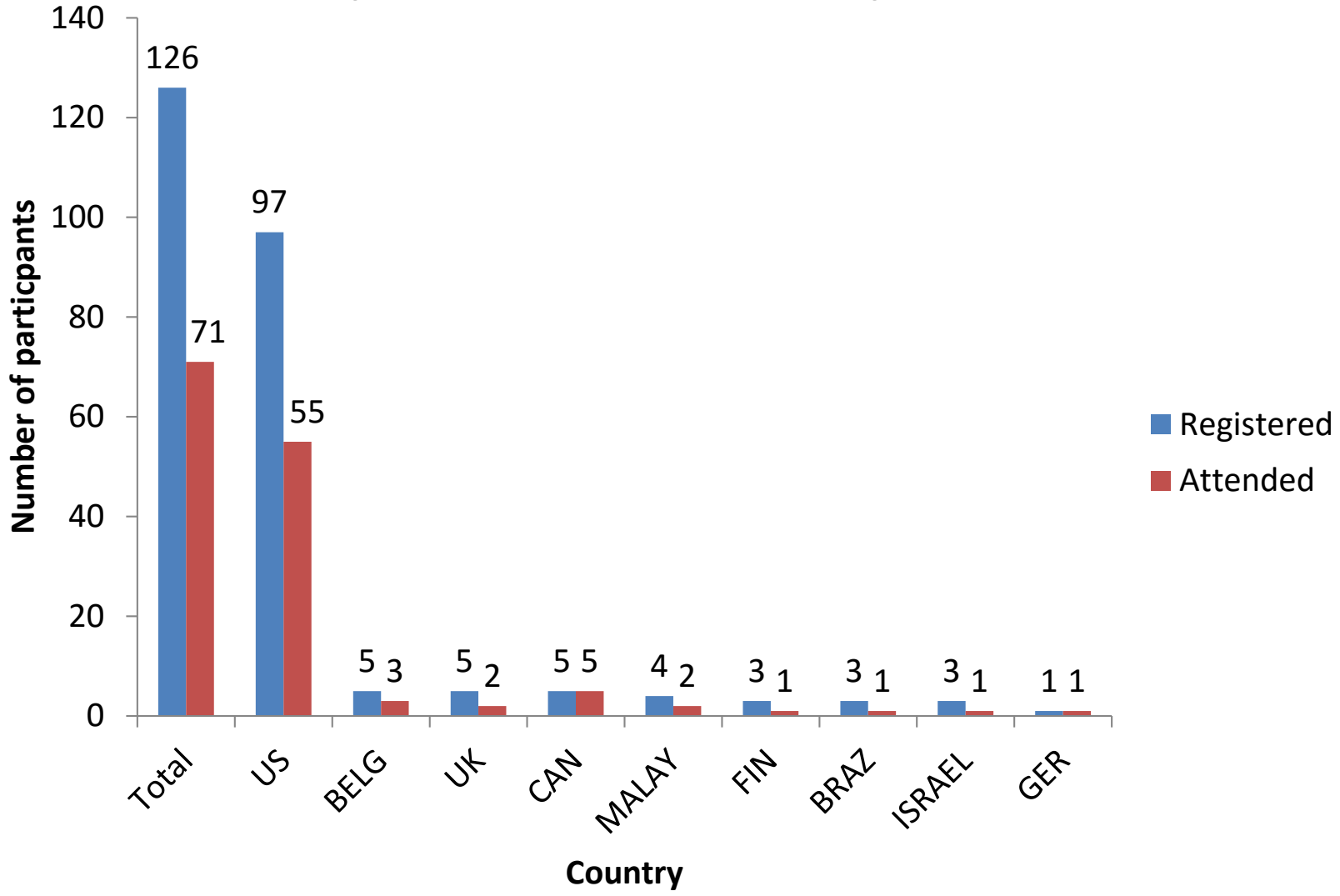
Participation by Country: Lead-free Solder Basics



Participation by affiliation: Tin whisker basics 12 Sept 2017 and 26 Sept 2017



Participation by country: Tin whisker basics 12 Sept 2017 and 26 Sept 2017

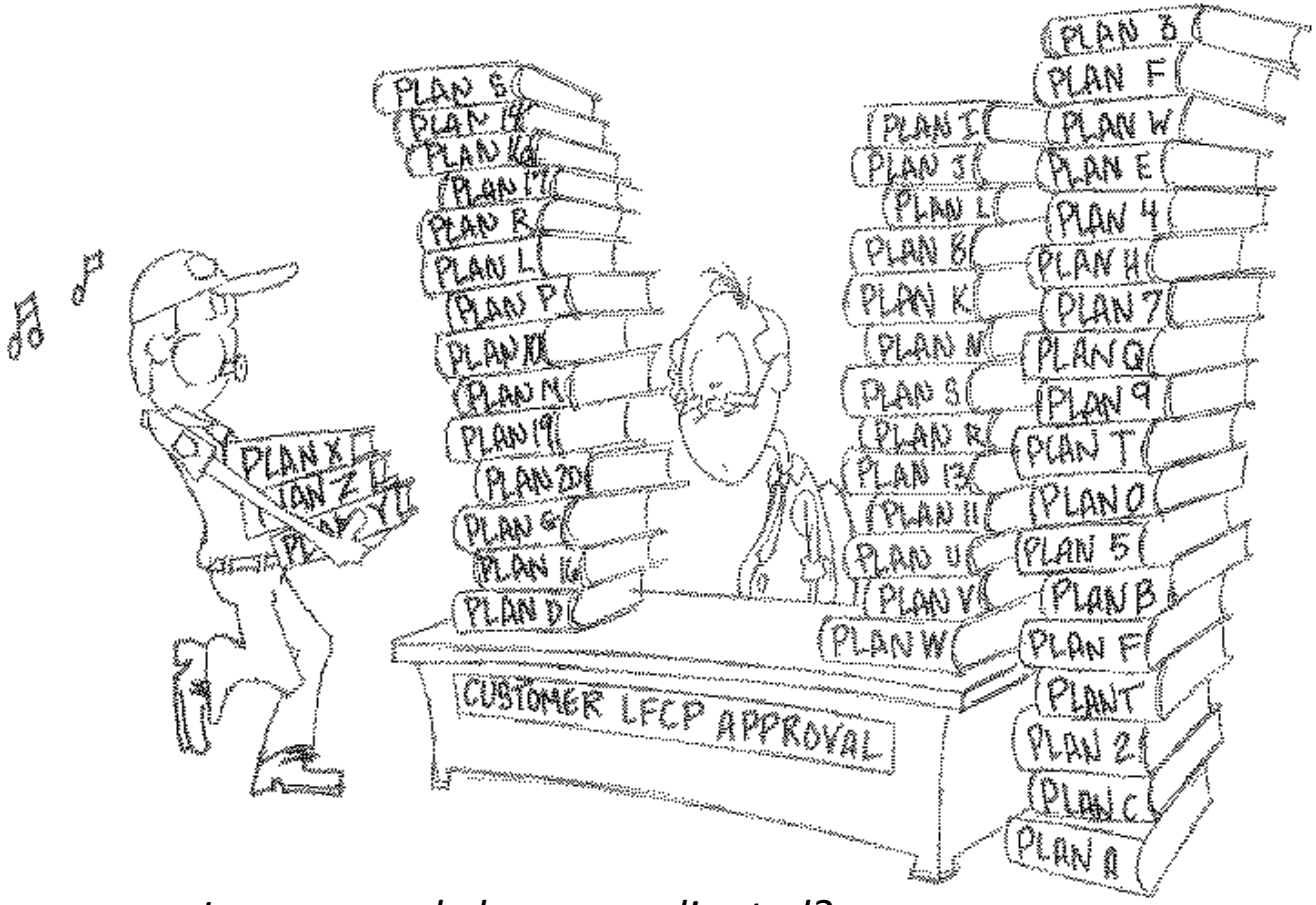


Impressions

- Reaching the procurement community remains challenging
  - Best practice: Call out Lead-free Control Plan Data Item Description DI-MGMT- 81772
- DoD is a top-down organization
  - Responds best when policy exists
    - No policies for lead-free risk management
    - For years there was a no new policies policy
  - Many processes already exist to handle lead-free factors, but need additional actions
    - Need DAG (Defense Acquisition Guide) to include revision containing lead-free identification and control
  - Short program manager tenure compounds problem
  - Programs cannot/will not talk about whisker issues
    - Security
    - Cost/Resources – often additional study needed to make info generic so it can be released
    - Proprietary information restrictions can make details difficult to find
  - Long term risk competes with bigger immediate issues
    - Cyber threat
    - Counterfeit parts
    - Etc.

Lead-free one of many issues

(1) Ref. L.P. Temple 2013, Implosion: Lessons from National Security, High Reliability Spacecraft, Electronics, and the Forces that Changed Them. SME = Subject Matter Experts



Is your supply base coordinated?
Is your team trained and ready for the review?

QUESTIONS

Electronics/COTS Discussion

- Can the DoD electronics reliability resources from 20 years ago help?
  - China Lake
  - Mantec
  - ONR, AFRL, Rome Labs, etc.
- COTs devices are not going to change to improve reliability beyond their needs if there is any cost increase
  - Tin whisker mitigation or solder reliability
- COTs Options
  - Use as is
    - Recognizing that new technology will be in every few years that may require requalification
  - Modify/adapt
    - Ruggedize, modify enclosures to restrict environments
  - Procurement/Programmatic mitigations
    - Planned refresh/replacement
  - Design your own COTs variation
    - Select which COTS parts can work
    - Stretch existing practices to longer term service
    - Insert selected new technologies

BACK – UP SLIDES

PROGRAM MANAGER WEBINAR (SELECTED SLIDES)

Overview

- Global restrictions on lead increasing
  - **2006** Consumer electronics European RoHS legislation
    - 2014-2017 evolved to include servers, telecom, medical …
- DoD/supplier technical community work
  - DoD very reliant on consumer parts and materials
  - Lead-free **NOT Form–Fit–Function** interchangeable
- **Recommendations to programs**
  - **Establish a lead-free control plan (LFCP)**
    - **Materials configuration, use coating for tin whisker mitigation**
    - Use **SAE GEIA-STD-0005-1**
    - Flow down **subcontract data item DI-MGMT- 81772**
  - **Existing tin-lead qualified programs**
    - Are non-qualified **lead-free leaking in? What is new whisker risk?**
    - **Increased cost** to track changes/monitor materials
  - **New programs**: Stay tin-lead or go lead-free
    - **For lead-free:** Select alloy, create design rules, develop test protocols, mfg processes, …

Land

Air

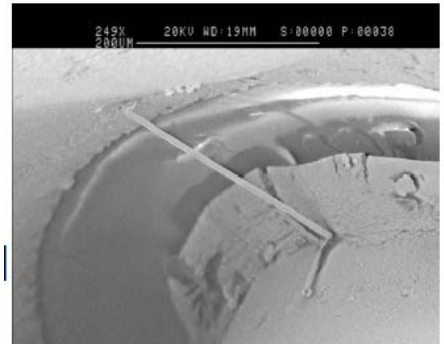
Sea

A material alone is not unreliable;
The design's use of a material determines reliability

RoHS = European Union Reduction of Hazardous Substances Legislation https://www.gov.uk/guidance/rohs-compliance-and-guidance

Lead-Free electronics – Failure modes & issues

- **Tin whiskers (and zinc whiskers)**
  - Electrical shorts
  - Metal shards, contamination
  - Arc flash metal vapor arc risk
- **Environmental Effects**
  - **Harsh** thermal cycling, shock & vibration
    - **Lower life and brittle interface fractures**
  - **Thermal aging** reduces solder strength
  - **Some early fails beyond ESS defect screening**
- **Configuration control problems**
  - Mixed lead(Pb) and lead-free **inventory**
  - Unidentified component materials
- **Sustainment/Repair**
  - **Incompatibilities** with tin-lead solder
  - **Less-repairable** assemblies



Whisker short circuit failure on a legacy missile accelerometer

Cracked solder joint open circuit

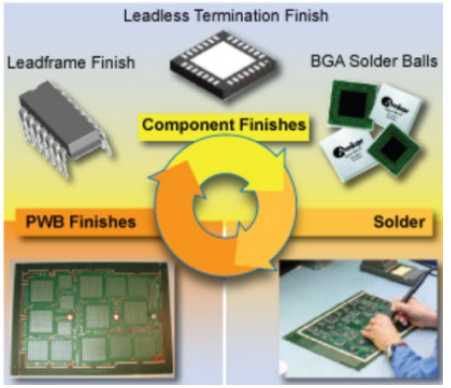
Electromagnetic relay short circuit; 115V metal vapor arc in air

Still DoD unknowns; Mitigate unquantifiable reliability impacts

ESS = environmental stress screening test for manufacturing defects

Added tasks for Program Managers/Systems Engineering

- ✓ Check contract terms and conditions and data items for lead-free requirements
- ✓ Create requirement definitions
- ✓ Make program level lead-free electronics decisions
  - SAE GEIA-HB-0005-1 Program Managers Handbook
  - Cost and schedule impacts for mitigations
- ✓ Create a lead-free risk management plan
  - Supplements gaps in standard reliability requirements
  - SAE GEIA-STD-0005-1 Lead-free Control Plan (LFCP)
- ✓ Inform suppliers of lead-free decisions
  - Subcontract LFCP flow down data item: DI-MGMT- 81772



Multiple lead-free impact areas and a global supply chain

Open item for lead-free solder: No industry consensus for "Objective evidence for reliability" in harsh MIL environments
Lead-free requires testing, analysis and modeling beyond tin-lead

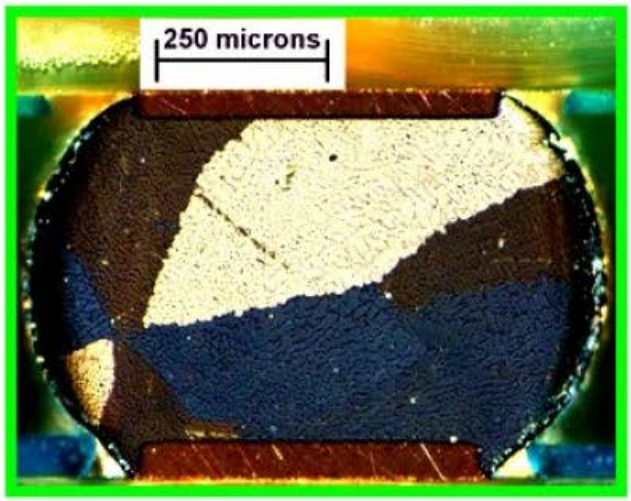
Lead-free is a continuing DoD issue because…

- **Open item: "Objective evidence for reliability" ← Needs investment**
  - Lead-free **requires testing**, analysis and modeling **beyond heritage tin-lead**
  - Industry **consensus lacking**
  - Important to precisely **define end use thermal, vibration, and shock over time**
- **Reliability requirements** have always been flowed down
  - **But,** analysis is based on **out-of-date standards** and 40 years of tin-lead use
    - e.g. **No tin plating/tin whisker factor in MIL-HDBK-217** reliability calculations
- Systems are increasingly using lead-free electronics
  - COTs to meet **costs and delivery schedules**
  - **Whisker mitigation levels differ** due to requirement interpretation variations
- **Supply chain process modification needed** to ensure lead-free material set reliability
  - More important than ever: Document and validate **all** lead-free electronics content
- Repair/Sustainment
  - **DoD owns equipment longer than some companies exist**
  - Need to know what materials are used where

Need to have a well informed customer and supply chain

LEAD-FREE SOLDER BASICS FOR SYSTEMS ENGINEERS (SELECTED SLIDES)

No-Pb Solder Reliability Overview



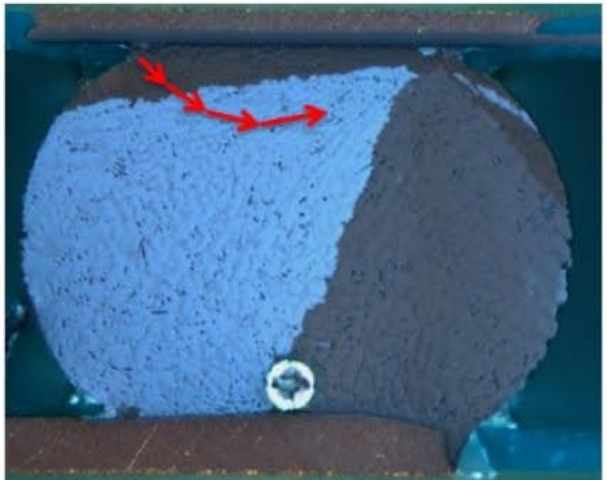
- No-Pb is not a disaster, can be dealt with.
- Reliability can be better, equal to or, worse than SnPb, depending on specifics
- ***Usually***, you are going to be OK with current practices, but there are too many surprises

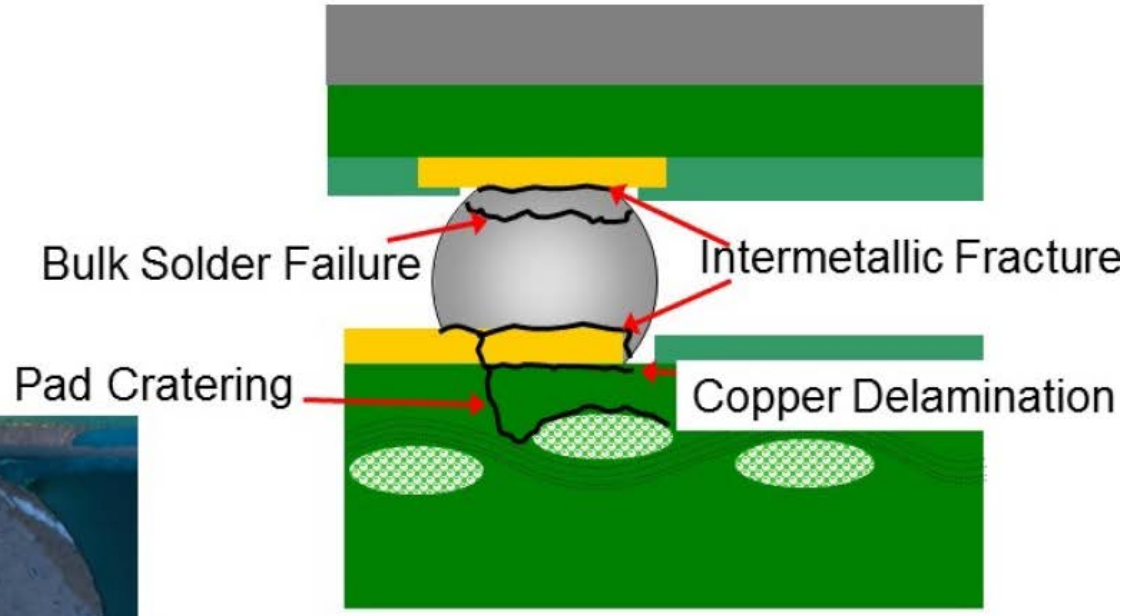
Take Away

- 'Expect' surprises – when is similarity analysis not OK?
- General background and outline of practical recommendations.
- Read technical parts of standards and handbooks.
- Final report on underlying SERDP project available

Damage and Failure

Vibration, cyclic bending, repeated drops, ... at constant temperature often lead to IMC failure or cratering

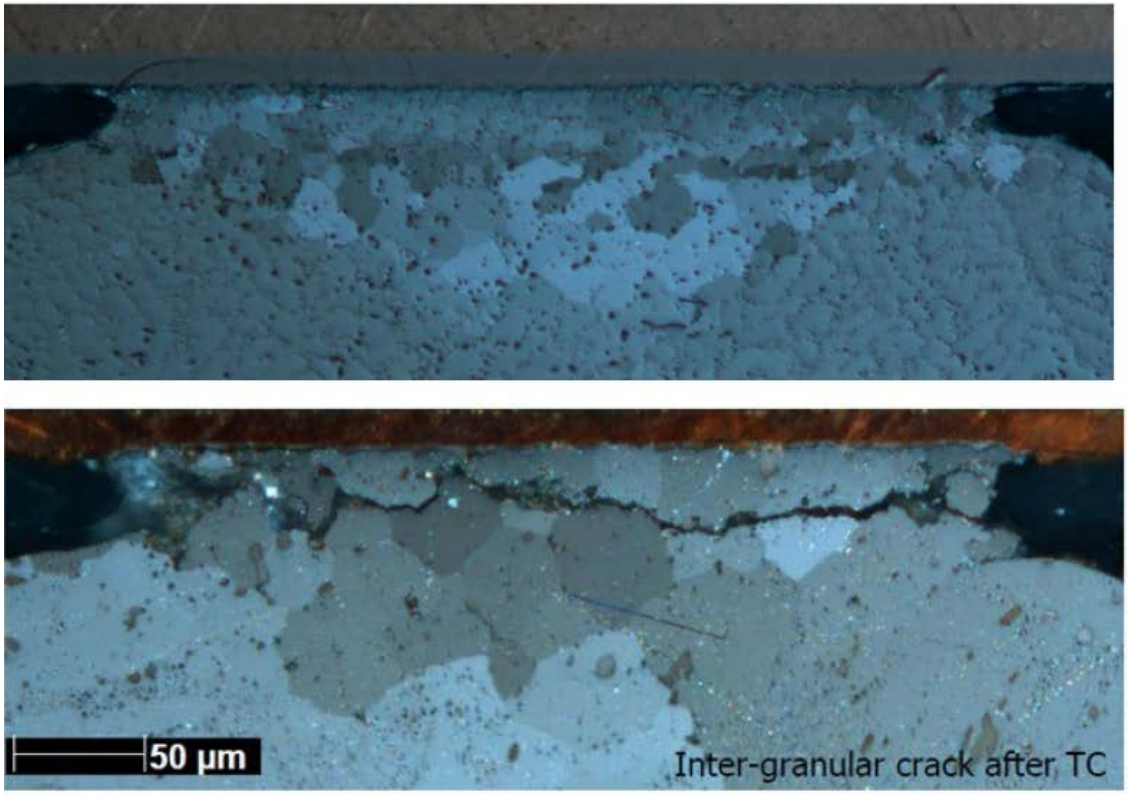




Depend on solder properties (alloy, pad finishes, process, aging, ...)

Damage and Failure

Thermal cycling leads first to recrystallization across high strain region, and then cracking along network of grain boundaries



Process is understood:

scaling with work during high temperature dwell

Summary

- ✓ Properties are determined by microstructure
- ✓ Initial microstructure depends on design and process
- ✓ Microstructure keeps changing with storage and use conditions
- ✓ Life in vibration likely scaling with work per cycle, but Miner's rule doesn't work
- ✓ Life in thermal cycling determined by precipitate coarsening plus work during high temperature dwell (not total work in cycle)
- ✓ This leads to surprises and greatly complicates
  - test requirements/protocols and interpretation of results ('best in test' often not 'best in service')
  - modeling
- ✓ Modeling requires our new constitutive relations, damage functions, and damage accumulation rules (for SnAgCu)
- ✓ Your ESS does much more damage than you think!

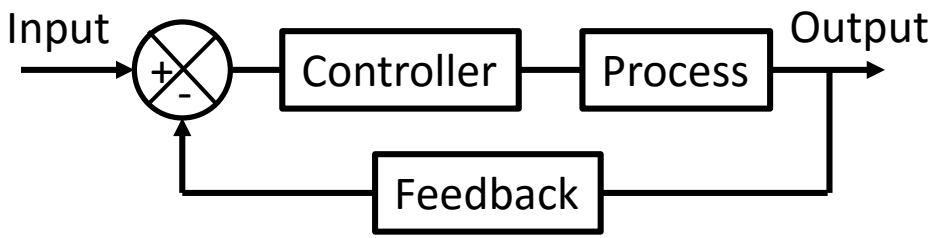
❑ **Similar work needed on non-SnAgCu alloys !!**

WHISKER BASICS FOR SYSTEMS ENGINEERS (SELECTED SLIDES)

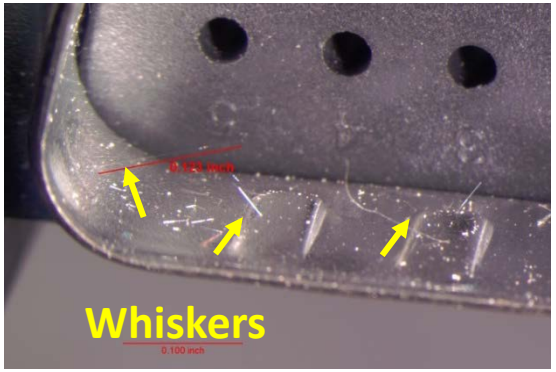
Whisker Webinar Overview

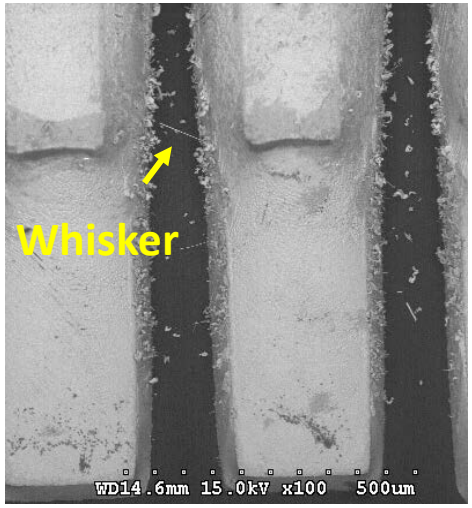
- Tin whisker description
- Factors influencing whisker growth
- Whisker events in industry
- Failure risk
  - Inspection
  - Electrical characteristics
  - Whisker movement
  - Metal vapor arcing
- Systems engineering
  - Systems design considerations
  - Role in contracting
  - System requirement details
  - Sub-tier supply chain flow down
  - Commercial – off – the shelf (COTS) electronics
  - Selecting a control level
  - Mitigating whiskers
    - Circuit considerations
    - Solder coverage
    - Conformal coating
    - Solder dipping
- Tin whisker risk assessment tools
- Case studies
  - Toyota accelerator pedal assembly
  - NASA Space Shuttle
- Summary
- Your every day tasks
- Back-up slides

System function

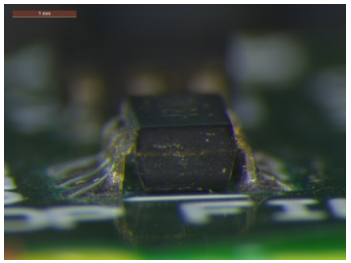


Connector shell





Sn-3Ag-0.5Cu Soldered assembly



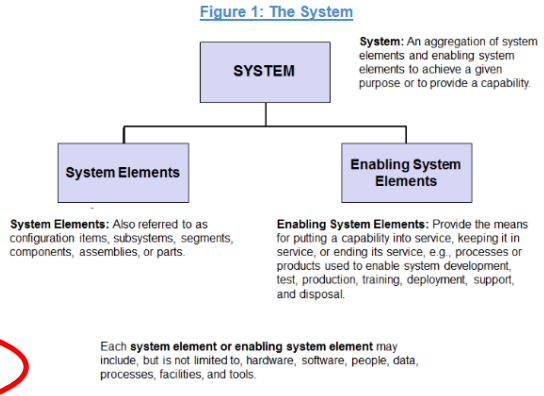
Electronic assembly

Defense Acquisition Guidebook (DAG)
tin risk items during procurement

CH 3–2.7 Systems Engineering Role in Contracting

Within the RFP development team, the Systems Engineer should be responsible for the technical aspects of the RFP and should perform the following actions:

- Referencing current required operational documentation and system performance specifications.
- Identifying SE process requirements (for example, requirements management, **configuration management and risk management**; see CH 3–4. Additional Planning Considerations).
- …
- Identifying any **design considerations including production; reliability and maintainability (R&M);** environment, safety and occupational health (ESOH); human systems integration (HSI); and security.
- Identifying for delivery Government-required technical data rights produced by the developer.
- Listing and describing **technical assessment evidence** and events, including technical reviews, audits, and certifications and associated entrance/exit criteria
- ….
- Coordinating with **Chief Developmental Tester with regard to the test and evaluation requirements**.
- Providing a requirements **verification traceability** database (requirements and test method).
- …..
- Leading or supporting the **technical evaluation during source selection**, to include providing inputs to the development of source selection criteria.
- **Performing schedule risk assessments** as part of the source selection evaluation process.
- ….
- Identifying external or SoS interfaces and **ensuring the technical interface requirement and task scope are unambiguous to** the offerors.
- …..
- Providing a clear description of the **minimum technical requirements used to determine the technical acceptability of a proposal.**



Key discussion points

See also http://sebokwiki.org/wiki/Procurement_and_Acquisition

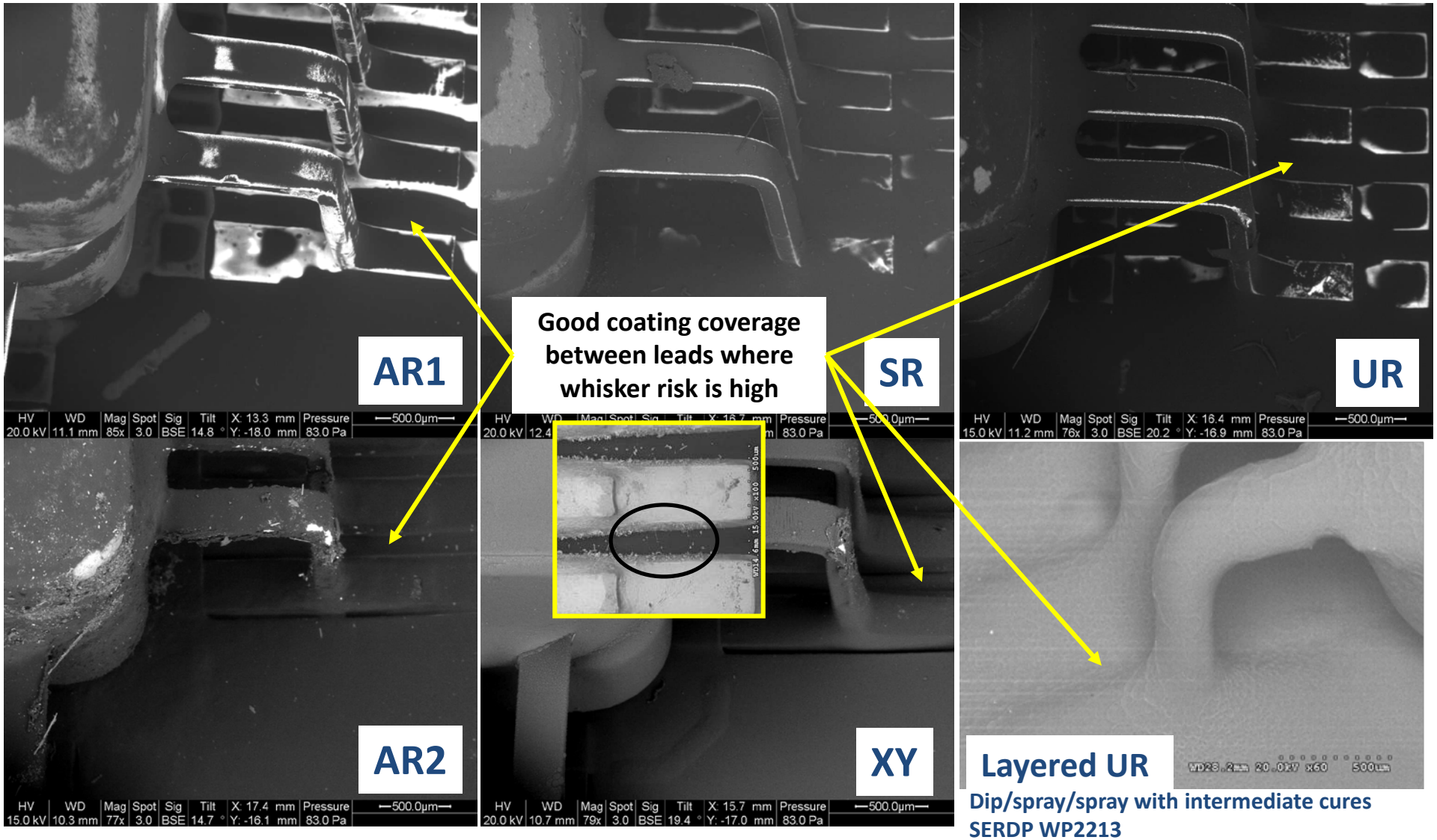
Just requiring 20 year life is insufficient
Lead-free risk mitigation requirements should be clear in the proposal and contract

Lead-free systems requirements details

- Where:
  - Systems engineering management plan (SEMP)
  - **Systems safety plan (SSP)**
  - Sub-contracts statements of work
  - Equipment specifications
- Creation of specification
  - Equipment **safety, availability and reliability**
    - Can a reboot clear a whiskers? Can the mission tolerate the reboot time?
  - Lead-free control
    - GEIA-STD-0005-1 Lead-free reliability, configuration management, repair, etc.
    - GEIA-STD-0005-2 **Tin whisker risk management** requirements
    - Sub-tier flow down using Lead-free Control Plan Data Item Description **DI-MGMT- 81772**
    - Can include in Parts Materials and Processes (PMP) section
  - Impacts validation testing and analysis by similarity requirements
  - "Class 2" change definition
    - Class 1: Solder alloy changes?
    - Class 2: Tin finish with mitigation per lead-free control plan?
  - Commercial-off-the-shelf (COTS) electronics use
    - Permit/restrict RoHS compliant lead-free electronics?
- Review/acceptance of specification
  - Requirements versus standard design/build processes
  - Lead-free control plan review with customer
  - What kind of safety, availability and reliability risk is being transferred to you?

RoHS = European Union Reduction in Hazardous Substances Legislation

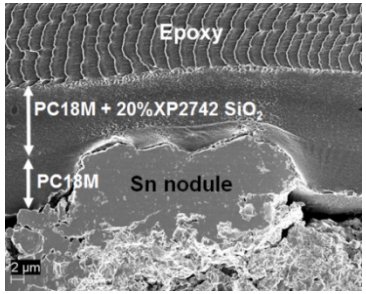
Comparison of Coating Coverage



IPC Project 5-22ARR Coating coverage state of the industry evaluation in process
Parylene (Type XY) has best coverage, has expenses and can be challenging to rework

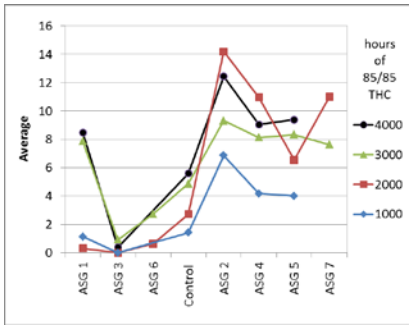
Mitigation research

Nanoparticle strengthened urethane and layered coating for enhanced coverage (SERDP WP2213)



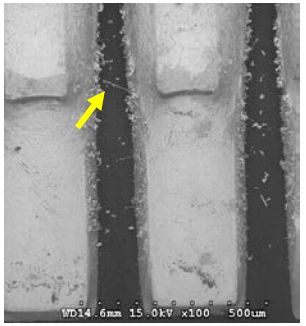
Nanoparticle filled layer over unfilled layer resists nodule penetration

Tin Whiskers Inorganic Coatings Evaluation (SERDP WP2212)



Alkali Silica Glass (ASG3) w/alumina nanoparticles lower whisker density

Tin whisker testing (SERDP WP1753)

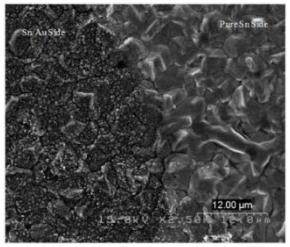


SnAgCu solder can grow whiskers when it becomes thin like tin plating. High cleanliness reduces whisker growth. Interrupting humidity testing stops whisker growth.

Whisker Tough™ coating MDA SBIR Steve Smith

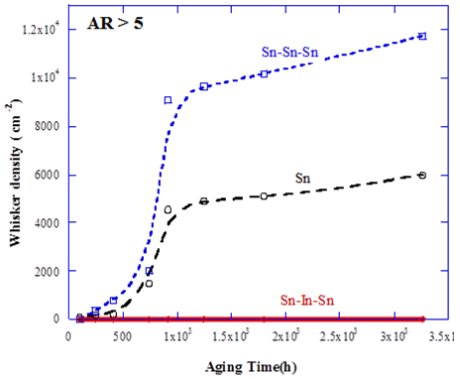
Very high elongation tough coating resists whisker penetration (DMC 2010)

The Role of Trace Elements in Tin Whisker Growth (SERDP-WP1751)



Au, Ge, or Sb additions to Sn substantially reduced whisker growth

Sn-In alloy (I. Dutta WSU)

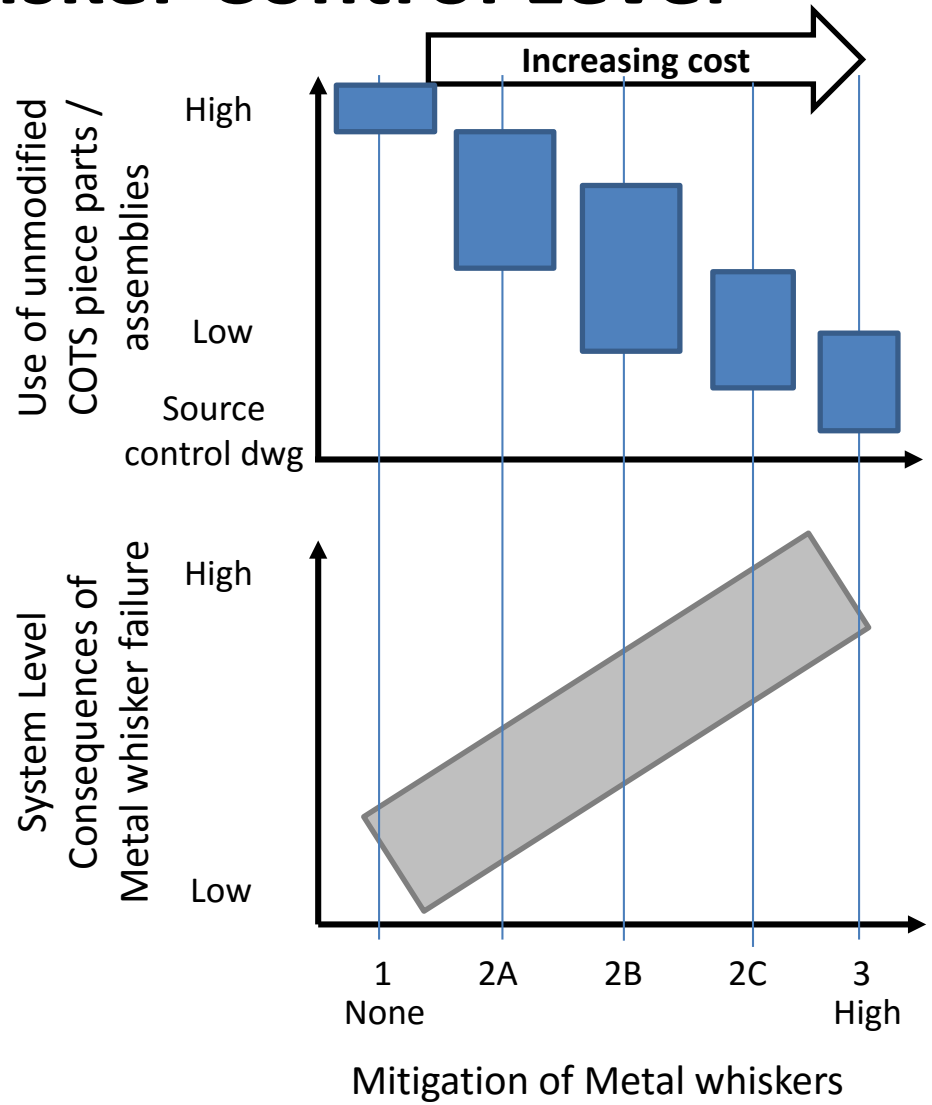


5-10% Indium in Sn significantly retards whisker nucleation during 10 month room temp. test

Others: Photonic Sn sintering (CALCE), Vacuum deposited fluorocarbon coatings NAVY SBIR (http://www.gvdcorp.com/why-gvd/technology), Electroless Ni Metal Cap plating over Sn (Landman), etc...

Selecting a Tin Whisker Control Level

- GEIA-STD-0005-2 Requirements for tin whisker mitigation
- Control levels
  - Level 1: No control
  - Level 2A and 2B: Moderate/high control
    - Many commercial parts with review and modification
  - Level 2C and 3: Very high control
    - Many source control part drawings and custom parts
- Selection factors in GEIA-STD-0005-2 include
  - Consequences of system failure
  - Accessibility for repair
  - Safety, availability and reliability
  - System redundancy
  - Anomaly detection
  - Possible plasma events



See also:
https://www.reliabilityanalysislab.com/tl_dp_0403_TinWhiskerRiskMitigation.html

Summary and Conclusions

- Unintended introduction of lead-free tin-rich materials can significantly increase failure risk including tin whisker short circuit risk
- All pure tin and Pb-free tin alloy finishes appear to be susceptible to whisker formation
- Part supplier mitigation strategies show varying levels of effectiveness
- Solder dip found to be effective
  - But, may not be applicable to all parts and be careful about coverage
- Solder assembly mitigation must confirm solder coverage and thickness
- Conformal coat reduces the probability of whisker short but may not completely contain whiskers
  - Coverage in application remains a critical concern
    - Parylene found to have the best coverage (vacuum deposited, challenging special rework, watch out for connector contacts)
    - Sprayed coatings may have lower coverage (Most commonly used, easiest to apply and rework. Often used in combination with assembly solder mitigation)
- Failure risk due to tin whisker formation is application dependent and should be assessed based on defined geometries and whisker growth characterizations
- Best practice:
  - GEIA-STD-0005-1 & 2 Lead-free control plans
  - OEMs should develop a plan for mitigating risk due to tin whisker formation
  - Include lead-free control plan flow down to sub-tier suppliers

Lead-free Control Plan
Data Item Description DI-MGMT- 81772

Title: Lead-Free Control Plan (LFCP)
Number: DI-MGMT- 81772
Approval Date: 20090612
AMSC Number: N9072
DTIC Applicable: N/A
Office of Primary Responsibility: SEA04RM
Applicable Forms: N/A

DI-MGMT-81772 can be found at http://quicksearch.dla.mil/ then inputting DI-MGMT in the Document ID field and 81772 in the Document No. field.

Use/Relationship: The Lead-Free Control Plan (LFCP) will be used to obtain essential information from contractors on how they plan to manage the risk of lead-free solders or finishes used in their products during the program's lifecycle.

This DID contains the format and content preparation instruction for the data product generated by the specific and discrete task requirement as delineated in the contract.

This DID is applicable to all new contracts and solicitations that acquire electronic systems including weapons systems containing electronic components as well as rework or repair of electronic systems or components.

The DID may also be applicable to systems already in production for major changes and block upgrades.

The reference documents cited in this DID, GEIA-STD-0005-1, "Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-Free Solder" and GEIA –STD-0005-2, "Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems", may be obtained from: Government Electronics and Information Technology Association, 2500 Wilson Boulevard, Suite 1100, Arlington, VA 22201, or as specified in the contract.

Requirements:

1. Reference documents. The applicable issue of any documents cited herein, including their approval dates and dates of any applicable amendments, notices, and revisions, shall be as specified in the contract.

2. Format. The LFCP shall be presented in the contractor's own format.

3. Content. The LFCP shall contain all of the information specified in GEIA-STD-0005-1 and GEIA-STD-0005-2.

3.1 Lead-Free Solder and Finishes. The plan shall address all lead-free solders and lead-free tin finishes in delivered products.

3.1.1 Reliability. The processes and materials utilizing lead-free solder or finishes shall be identified as capable of producing items that meet product reliability requirements.

3.1.2 Configuration Control and Product Identification. The configurations of all systems, assemblies, subassemblies, and parts shall be included and identified by version and applicable configuration identifier.

DI-MGMT-XXXX (Cont'd)

3.1.3 Risks and Limitations of use. Any risks or limitations on the use of the products due to the incorporation of lead-free solder or finishes shall be identified along with information on how to manage those risks or limitations.

3.1.4 Tin (Sn) Whiskers. Any harmful effects of Sn whiskers resulting from use of lead-free tin shall be addressed.

3.2 The plan shall contain any recommendations or changes to the product design and any contract modifications required to comply with the LFCP.

End of DI-MGMT- 81772

SAE GEIA standards summary

- SAE GEIA-STD-0005-1
  - Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solders
- SAE GEIA-STD-0005-2
  - Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems
- SAE GEIA-STD-0005-3
  - Performance Testing for Aerospace and High Performance Electronic Interconnects Containing Lead-free Solder and Finishes
- SAE GEIA-HB-0005-1
  - Program Management/Systems Engineering Guidelines for Managing the Transition to Lead-free Electronics
- SAE GEIA-HB-0005-2
  - Technical Guidelines for Aerospace and High Performance Electronic Systems Containing Lead-free Solder and Finishes
- SAE GEIA-HB-0005-3
  - Rework/Repair Handbook to Address the Implications of Lead-free Electronics and Mixed Assemblies in Aerospace and High Performance Electronic Systems
- SAE GEIA-STD-0006
  - Requirements for Using Solder Dip to Replace the Finish on Electronic Piece Parts

DoD systems lead-free resources

- ARMY AMRDEC
  - MIL-STD-11991 (Missile Systems) contractual deliverable using DI-STDZ-81993
- Require LFCP using DI-MGMT-81772
- DMEA - Defense Microelectronics Activity
- NAVY – Office of Naval Research – Best Manufacturing Practices Center of Excellence
- Air Force - Defense Standardization Program Office (DSPO) Parts Standardization and Management Committee (PSMC) participation
- SERDP/ESTCP Research
- Defense Acquisition University
  - Lead-free Electronics Training
  - CLL 007 Training Module Lead Free Electronics Impact on DoD Programs
- Lead-free Manhattan Project Reports

Lead-free research resources

- SERDP/ESTCP – DoD Strategic Environmental Research and Development/ Environmental Security Technology Certification Program
  - Lead Free Webinar Slides
  - Microstructurally Adaptive Constitutive Relations and Reliability Assessment Protocols for Lead Free Solder
  - Novel Whisker Mitigating Composite Conformal Coat Assessment
  - Tin Whisker Testing and Modeling
  - Contributions of Stress and Oxidation on the Formation of Whiskers in Lead-Free Solders
  - Tin Whiskers Inorganic Coatings Evaluation (TWICE)
  - The Role of Trace Elements in Tin Whisker Growth
- IPC/PERM Round Robin Studies
  - IPC Coating coverage 5-22ARR
  - IPC PERM Group 8-81f Tin-lead solder self mitigation
  - IPC PERM Group 8-81h Tin whisker mitigation
- Auburn University - Center for Advanced Vehicle and Extreme Environment Electronics
  - Various projects studying lead-free solder reliability and tin whiskers including studying drop shock and aging effects
- CALCE University of Maryland – Center for Advanced Life Cycle Engineering
  - Several project and tools related to Lead-free and Tin Whiskers
- Binghamton University - Integrated Electronics Engineering Center (IEEC)
  - Various projects studying lead-free solder reliability, tin whiskering and conformal coating mitigation
- AREA Universal Instruments Corp. - Advanced Research in Electronics Assembly
  - Various projects studying lead-free solder reliability with an emphasis on manufacturing processes and microstructure
- Joint Council of Aging Aircraft (JGPP) Lead-free testing completed on four lead-free solder alloys. Results published
- NASA DoD Phase 3 Lead-free test in process, but funding limited
- Sandia National Labs and Ames Labs
  - Lead-free solder alloy development and tin whisker research
- NASA Goddard
  - Tin whisker website
- NASA – Jet propulsion lab
  - Working on IPC standards for lead-free assembly reliability test protocols
- NASA – Kennedy Space Center
  - TEERM Office NASA-DoD Lead-Free Electronics (Project 2) Project Number: NT.1504NASA – DoD Phase 2 and Phase 3
- NIST
  - Archive of solder properties
- National Defense Center for Energy and Environment (NDCEE)
  - Demonstration/Validation Testing of X-Ray Fluorescence (XRF) Technology to identify Lead-free Electronics and Solder Categories
  - Development of Lead-free Training Courses and a Lead-free database

LFCP TEMPLATE TABLE OF CONTENTS

(based on SAE GEIA-STD-0005-1 Revision A May 2012)

Lead-free Materials Systems Risk Areas

Defense Acquisition Guidebook (DAG) Risk Management CH 3–4.3 Design Considerations

Table 42: Design Considerations

	Design Consideration	Section Number
	Accessibility (Section 508 Compliance)	4.3.1
→	Affordability - SE Trade-Off Analysis	4.3.2
→	Anti-Counterfeiting	4.3.3
→	Commercial-Off-the-Shelf (COTS)	4.3.4
→	Corrosion Prevention and Control (CPC)	4.3.5
→	Critical Safety Item (CSI)	4.3.6
	Demilitarization and Disposal	4.3.7
→	Diminishing Manufacturing Sources and Material Shortages (DMSMS)	4.3.8
→	Environment, Safety and Occupational Health (ESOH)	4.3.9
	Human Systems Integration (HSI)	4.3.10
	Insensitive Munitions	4.3.11
	Intelligence (Life-cycle Mission Data Plan (LMDP))	4.3.12
	Interoperability and Dependency (I&D)	4.3.13
	Item Unique Identification (IUID)	4.3.14
→	Modular Design	4.3.15
	Operational Energy	4.3.16
	Packaging, Handling, Storage and Transportation (PHS&T)	4.3.17
→	Reducibility, Quality & Manufacturing (PQM)	4.3.18
→	Reliability & Maintainability (R&M) Engineering	4.3.19
	Spectrum Management	4.3.20
→	Standardization	4.3.21
→	Supportability	4.3.22
→	Survivability (including CBRN) & Susceptibility	4.3.23
	System Security Engineering (SSE)	4.3.24

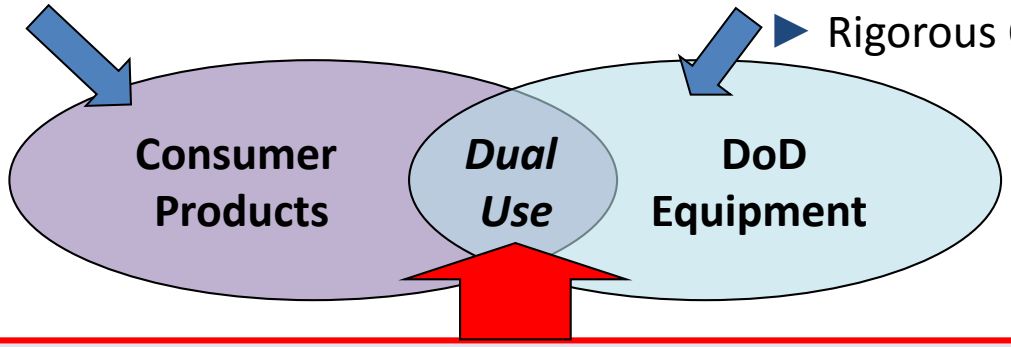
Lead-free materials factor into many aspects of the system

DoD COTS Electronics Dependence

Commercial versus DoD Electronics Usage

- 1-2 Year Life, No repair
- Non-Safety Systems
- "Fractions of a Cent" Cost Drivers
- RoHS Compliant
- Rapidly Changing

- Complex Systems
- 10-20+ Year Service
- High Performance
- Critical Safety Items
- Rigorous Qualification



Consumer Electronics Supply Base Will Not Accommodate or Solve DoD Harsh Operating Environment Reliability Issues

- Many, but not all Pb-free electronics issues for consumer products will be resolved by commercial electronics manufacturers (mostly in China & Asia)

- COTS electronics issues to be solved for DoD applications:
  - Tin whiskers
  - Reliable operation in harsh environments
  - Repair and sustainment

Financial Implications of Retaining SnPb

- **Discrete Semiconductors**
  - These parts typically cost from $4 to $0.2 but usage is high
  - Some component suppliers still providing SnPb finished parts, but….
    - One OEM assessment finds:
      - **$300K/yr** to purchase SnPb instead of the Tin equivalents
      - **25 week** Lead-times encountered often
- **Incoming inspection for SnPb**
  - Pb-free findings have high impact to production in "just in time" production
    - NASA Finding: **~5% of parts specified to be SnPb are coming in with the Pb-free finishes**

- **OnSemi Product Change Notice (PCN)**
  - Product Change Notice PCN 16389
    - 4Q09 (4th QUARTER 2009) Product Discontinuance Notice
    - LAST BUY DATE: 21-Jul-2010
  - 456 SnPb parts being replaced by Pure tin parts
    - Parts disposition program by program
      - Use as is – but what is whisker risk?
      - Reprocess to get SnPb altered part
      - Life time buy

			PLATING							
			Sn [%]	Pb [%]	Ag [%]	Cu [%]	Pd [%]	Au [%]	Ni [%]	Weight [mg]
Base part	Part	Status	7440-31-5	7439-92-1	7440-22-4	7440-50-8	7440-05-3	7440-57-5	7440-02-0	
1.5SMC47A	1.5SMC47AT3	Lifetime	80.00	20.00						2.51
1.5SMC47A	1.5SMC47AT3G	Active	100.00							2.51
	SZ1.5SMC47AT3	Obsolete	80.00	20.00						2.51
	SZ1.5SMC47AT3G	Active	100.00							2.51

  - One OEM example: BAS16LT3 Diode, 75V, 200MA
    - **1908 configurations** (production or fielded) use this part
    - **105 programs** (or variants) impacted

$$ Impact: All DoD OEMs are evaluating their use of these 456 parts

Maintaining SnPb Requires Significant Effort